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TRADE-IN-GOODS AND TRADE-IN-TASKS: AN INTEGRATING FRAMEWORK

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ABSTRACT

Our paper integrates results from trade-in-task theory into mainstream trade theory by developing trade-in-task analogues to the four famous theorems (Heckscher-Ohlin, factor price equalisation, Stolper-Samuelson, and Rybczynski) and showing the standard gains-from-trade theorem does not hold for trade-in-tasks. We show trade-in-tasks creates intraindustry trade in a Walrasian economy, and derive necessary and sufficient conditions for analyzing the impact of trade-in-tasks on wages and production. Extensions of the integrating framework easily accommodate monopolistic competition and two-way offshoring/ trade-in-tasks.

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1. Introduction

A growing list of economists argue that the nature of international trade is changing in important ways (inter alia, Jones and Kierzkowski 1990, Grossman and Rossi-Hansberg 2006, 2008, Blinder 2006, 2009, Hanson, Mataloni and Slaughter 2005, and Hummels, Ishii and Yi 2001). Instead of simply creating more trade in goods, global integration is increasingly marked by "trade in tasks" – as Grossman and Rossi-Hansberg (2006) labelled it – that is to say, more trade of intermediate goods and services due to the widespread emergence of offshoring.

This trend has elicited a substantial number of theoretical contributions that characterise the impact of this type of international commerce. To date, this body of theory is marked by a wide range of cases where unexpected outcomes are common – many of which seem to contradict standard trade theory's received wisdom.

The goal of our paper is threefold. First, we present a simple but flexible analytic framework in which both trade-in-goods and trade-in-tasks arise endogenously in response to exogenous changes in the cost of moving goods and ideas. Second, we use the framework to integrate results from trade-in-tasks theory into mainstream trade theory. For example, we develop trade-in-tasks analogues to the four famous trade-in-goods theorems: Heckscher-Ohlin (HO), factor price equalisation (FPE), Stolper-Samuelson, and Rybczynski, and show that the standard gains-from-trade theorem for trade-in-goods does not hold for trade-in-tasks (i.e. some trade-in-goods is always better than none, but the same cannot be said of trade-in-tasks when trade-in-goods is already possible). Third, we show that our framework can integrate the many special-case results in the offshoring/trade-in-tasks theory. Additionally we show that trade-in-tasks creates intraindustry in a Walrasian economy, and that extensions of the framework easily accommodate monopolistic competition and two-way offshoring/trade-in-tasks.

Integrating trade-in-tasks theory with trade-in-goods theory is a challenge because they pose fundamentally different questions. Starting from a list of goods, factors and countries, mainstay trade theory studies the switch from no-trade to free-trade in goods. Trade-in-tasks/offshoring theory tackles a different intellectual exercise. Starting from an equilibrium where trade-in-goods exists, the theorist considers the impact of expanding the list of tradable goods – specifically of allowing 'fragments' of previously bundled production processes to be produced abroad, thus giving rise to trade in intermediate goods and services, i.e. trade-in-tasks.

The key to our integration is a transformation that permits analysis of trade-in-tasks' general equilibrium effects using the HO toolkit. The transformation turns on the insight that offshoring is like "shadow migration" – i.e. it is as if foreign factors migrated to the offshoring nation but were paid foreign wages. For example, the HO and HOV theorems fail to predict the trade-pattern impact of trade-in-tasks; we show that the theorems hold when "shadow migration adjusted" endowments are used instead of actual endowments. Foreign factors employed in offshore production are potentially observable, so the resulting propositions should be testable with firm-level datasets. On the dual side, the vector of cost-saving generated by "shadow migration" can be use to transform the FPE and Stolper-Samuelson theorems in ways that predict factor-price effects. The trade-in-tasks equilibrium conditions thus transformed, the HO toolkit is used to establish necessary and sufficient conditions for the wage, price, output, trade, and gains-from-trade effects of allowing trade-in-tasks.

1.1. The theoretical literature

The early HO theory incorporated trade in intermediate goods (Batra and Casas 1973, Woodland 1977, Dixit and Grossman 1982, and Helpman 1984) and the 1990s saw a number of informal analyses of fragmentation as well as some formal modelling (Deardorff 1998a, b, and Venables 1999). Trade-in-tasks issues, however, were more recently crystallised by Kohler (2004a), Markusen (2006), Antràs et al. (2006), and Grossman and Rossi-Hansberg (2006, 2008).

The most commonly cited reference in the early offshoring/fragmentation literature is the informal analysis of Jones and Kierzkowski (1990), which seems to be the first to leverage the insight that fragmentation acts as technological progress and should therefore be expected – as per Jones (1965, p.567) – to have complex wage effects. This line of modelling typically worked with small open economies where fragmentation occurs in only one sector and in one direction. The analysis is largely verbal or graphical with the focus firmly on wage effects.[1] The gallery of special cases varies along three axes: the offshoring nation's factor abundance, the factor intensity of the fragmenting sector and fragment offshored. Jones and Kierzkowski (1990), for

[1] See Jones and Marjit (1992), Arndt (1997, 1999), Jones and Findlay (2000, 2001), Jones and Kierzkowski (1998, 2000), Jones, Kierzkowski and Leonard (2002), and Francois (1990a, b, c).

instance, argue that workers whose jobs are "lost" to offshoring may, somewhat paradoxically, see their wages rise in some special cases.

Among the mathematical formalisations of fragmentation, Deardorff (1998a,b) studies fragmentation in a multi-cone HO model where cost-saving offshoring is driven by non-factor price equalisation. The focus is on factor prices and showing that trade-in-tasks need not foster wage convergence. Venables (1999) works with a 2x2x2 HO model where offshoring is cost saving due to non-factor price equalisation arising from a factor-intensity reversal. Fragmentation occurs in only one industry and in one direction. Numerical simulations and Lerner-Pearce diagrammatic analysis are employed to study examples where trade-in-tasks produces wage convergence and divergence. Kohler (2004a) works with a small-open-economy specific-factor model where fragmentation can only occur in one sector. The focus is on the reward to the specific capital that moves offshore when fragmentation occurs, and the overall welfare effects on the home nation. Markusen (2006) works with a multi-cone HO model that he simulates numerically assuming that fragmentation occurs in the skill-intensive sector and the fragment is of middle skill-intensity. He typically finds that skilled workers gain. Kohler (2004b) works with a small open economy where fragmentation/offshoring can only happen in one sector, using the Dixit and Grossman (1982) model with a continuum of intermediate goods; he shows that cheaper offshoring raises or lowers factor prices according to the relative factor intensity of the two sectors and the fragments offshored. No formal results are presented on production and trade effects, nor are necessary and sufficient conditions developed in any of these papers.

More recently, Grossman and Rossi-Hansberg (2006) present a perfect competition model where two final-goods are produced using two continuums of tasks, each employing only one type of labour. Offshoring arises endogenously and the range of tasks offshored varies continuously with the cost of offshoring. The resulting wage effects are ambiguous in general, but they highlight a special case where both sectors offshore only unskilled labour tasks and yet unskilled wages rise while skilled wages are unchanged (see detailed analysis of this case in Section 3.4 below). The paper formalises the analogy between offshoring and technological change (the 'productivity effect') showing that trade-in-tasks, unlike trade-in-goods, can generate gains for all factors in the offshoring nation. The paper establishes necessary and sufficient conditions for wage-changes in the two-factor-two-good small open economy case. It also explores the novel "labour supply effect” that influences wages when there are more factors than goods. Trade and production effects are not explored.

Rodriguez-Clare (2010) embodies the Grossman-Rossi-Hansberg approach in a Ricardian model à la Eaton and Kortum (2002). He studies the impact of trade-in-tasks on the gains from trade for the home and host nations. Global welfare rises due to offshoring’s productivity effect, but terms-of-trade effect can mean that the home nation losses despite this. Antràs et al. (2006, 2008) propose a model in which all tasks are potentially offshorable. The focus is on the formation, composition and size of (cross-border) teams when workers have different abilities (skills), and countries have different skill endowments. Among other results, they show that improved communication technology yields larger teams and larger wage inequalities. Their model also provides a trade-induced explanation for the rise in returns to skills.

In summary, the trade-in-tasks/offshoring literature illustrates that standard trade theorems are not good at predicting the wage effects of allowing trade-in-tasks. The literature has not systematically explored the production and trade-pattern effects, nor has any attempt been made to systematically integrate the predictions of trade-in-tasks models with standard trade theory.

1.2. Organisation of paper

The next section introduces notation by presenting a slightly modified HO model. Section 3 considers the impact of allowing offshoring/trade-in-tasks. Section 4 considers trade-in-tasks when the offshored intermediate goods/services can be sold to local firms instead of only being re-imported to the home nations as in the standard models. Section 5 shows the framework is flexible enough to be easily extended to allow for monopolistic competition and two-way offshoring. Section 6 concludes.

2. Trade in goods

To fix notation, this section presents an HO model modified slightly à la Trefler (1993); the modification creates an incentive for offshoring when the possibility arises in Section 3.

There are two countries, Home and Foreign (Foreign variables distinguished by asterisks), F factors of production, and I perfectly competitive industries ($f = 1,...,F$ and $i = 1,...,I$ index factors and industries respectively). The factor price, goods price, factor endowment, production, consumption and import vectors are denoted $\mathbf{w} \equiv \{w_f\}$, $\mathbf{p} \equiv \{p_i\}$, $\mathbf{V} \equiv \{V_f\}$, $\mathbf{X} \equiv \{X_i\}$, $\mathbf{C} \equiv \{C_i\}$ and $\mathbf{M} \equiv \{M_i\}$.[2] The $I \times F$ matrix $\mathbf{A}(\mathbf{w}) \equiv \{a_{fi}(\mathbf{w})\}$ and its transpose $\mathbf{A}^{\mathbf{T}}$ summarise Home's constant returns technology with typical element a_{fi} giving the cost-minimizing input requirement of factor f in industry i as a function of **w**. Tastes are homothetic and identical across nations. We adopt standard regularity conditions to ensure that a unique equilibrium exists with diversified production.[3] Our departure from the standard model is that Home is technically superior in the Hicks-neutral sense:

> **Assumption 1 (homothetic technologies)**. All Foreign unit-input requirements are $\gamma > 1$ times higher than Home's for any **w*** equal to **w**, (or – since factor demands are homogenous of degree zero – proportional to **w**).

Such Hicks-neutral technology differences do not create Ricardian motives for trade. As is well known, the model can be mechanically transformed into a standard HO model by defining Foreign factor supplies in 'effective units', i.e. dividing V_f^* by the technology gap γ. We denote effective units of factors by "~", so the world factor endowment in effective units is $\tilde{\mathbf{V}}^{\mathbf{w}} \equiv \mathbf{V} + \mathbf{V}^*/\gamma$.

The autarky equilibriums are characterised by market-clearing conditions **M* = 0** and **M = 0** as well as *I* pricing conditions and *F* employment conditions in each nation, which in familiar notation are:

$$\mathbf{p} = \mathbf{A}\mathbf{w}, \qquad \mathbf{p}^* = \gamma \mathbf{A}^* \mathbf{w}^* \qquad\qquad \mathbf{V} = \mathbf{A}^{\mathbf{T}}\mathbf{X}, \qquad \mathbf{V}^* = \gamma \mathbf{A}^{*\mathbf{T}} \mathbf{X}^* \tag{1}$$

where the arguments are suppressed, so **A(w)** and **A(w*)** are written as **A** and **A***.

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[2] Vectors and matrices are denoted by bold letters; variables and parameters by italics, and **Z** > **N** means that *each element* of **Z** exceeds the corresponding element of **N**.

[3] The condition is that the **V**'s lie in the Chipman (1967) 'diversification cone', i.e. the space spanned by the columns of $\mathbf{A}^{\mathbf{T}}$ evaluated at equilibrium factor prices.

When trade becomes free, goods prices are equalised (law of one price), goods-markets clear globally (**M*** + **M** = **0**), and (1) characterises the equilibrium but with a common **p**. Under standard regularity conditions, equilibrium production and price vectors are strictly positive.[4]

Throughout the paper, we assume **A** is invertible in which case the law-of-one-price can, and assuming no factor intensity reversals, must imply **effective factor price equalisation (FPE)**, i.e. $\mathbf{w} = \gamma\,\mathbf{w}^*$ – a fact established by simple manipulations of (1) using the fact that **A = A*** when $\mathbf{w} = \gamma\mathbf{w}^*$.[5] With homothetic preferences, the common **p**, and **A** = **A*** due to effective FPE, the effective-factor-content of **C** must be $s\tilde{\mathbf{V}}^w$ (s is Home's share of world income). The factor content of Home production is **V**, so the pattern of trade must respect the **HOV and HO theorems**:

$$\mathbf{A}^T\mathbf{M} = s\tilde{\mathbf{V}}^w - \mathbf{V} \qquad\qquad \mathbf{M} = (\mathbf{A}^T)^{-1}(s\tilde{\mathbf{V}}^w - \mathbf{V}) \tag{2}$$

The third and fourth standard theorems consider the impact on **w** of an exogenous variation in **p** (**Stolper-Samuelson theorem**) and the impact on **X** of an exogenous variation of **V** (**Rybczynski theorem**); these follow from simple manipulations of (1) given that **A = A*** under free trade.

The standard **gains-from-trade (GFT) theorem** states that some trade is better than none – ignoring intra-national distribution issues (Ohyama 1972, Smith 1982, Dixit 1985). As the GFT theorem analogue for trade-in-tasks does <u>not</u> hold (see Proposition 3), we review why it holds for trade-in-goods. By revealed preference arguments (Samuelson 1939, 1962, Kemp 1962), one equilibrium is preferred to another if the inferior equilibrium's consumption vector is affordable at the preferred equilibrium's prices. Denoting Home's autarky consumption vector as $\mathbf{C_a}$, the trade equilibrium is preferred by Home if $\mathbf{p}(\mathbf{C}-\mathbf{C}_a) \geq 0$. Using **M**'s definition, the condition can be written as $\mathbf{p}(\mathbf{M}-\mathbf{M}_a)+\mathbf{p}(\mathbf{X}-\mathbf{X}_a) \geq 0$. This inequality holds because: (i) the first term is zero due to balanced trade (**pM** = 0) and by autarky's definition ($\mathbf{M_a} = \mathbf{0}$), and (ii) profit maximisation

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[4] See the appendix of our working paper (http://www.dagliano.unimi.it/media/wp2008_250.pdf) for necessary and sufficient conditions for existence.

[5] While invertibility of **A** is far from innocuous (in particular, it requires $I = F$), the implications of relaxing the assumption are well understood (Ethier 1984).

by Home firms implies the second term is positive. A symmetric result holds for Foreign, so both nations gain from trade. The logic holds even for partial liberalisations of autarky (Dixit 1985).

3. Trade in tasks

This section modifies the model to allow trade-in-tasks. Production in industry *I* involves N_i tasks indexed by $t = 1,..., N_i$, $N_i \geq 2$. Tasks are either segments of the physical production process (so the task's output is an intermediate good, say wheels) or a slice of the necessary factor inputs (so the task's output is a productive service, say accounting services). In the model described above, all tasks were bundled into the unit-input-coefficient vectors $\{a_{fX}(\mathbf{w})\}_{f=1}^{F}$. This implicitly assumed that all tasks in a given production process had to be performed in a single nation. Here we consider an exogenous change that allows the production process to function even when tasks are spatially unbundled – thus opening the door to offshore production and the attendant trade-in-tasks. More specifically, each task involves a non-negative quantity of each factor *f*, so with constant returns, a_{fi} can be written as the sum of task-level coefficients:

$$a_{fi}(\mathbf{w}) \equiv \sum_{t=1}^{N_i} a_{fit}(\mathbf{w}); \qquad \forall\ f = 1,..., F;\ i = 1,..., I \tag{3}$$

where a_{fit} denotes the unit input requirement of factor *f* for task *t* in sector *i*. This allows substitutability of factors in the performance of individual tasks, but not of tasks. For, example if making wheels is one task then each car requires exactly 4 wheels; extra wheels cannot be substituted for the engine. A key additional assumption is:

Assumption 3 (firm-specific technologies). Firms that offshore a task can do so using their own nation's technology.[6]

This makes offshoring economical despite effective FPE. Home firms can combine their superior technology with lower Foreign factor prices, so Home-to-Foreign offshore may be economic; Foreign-to-Home offshoring will never be economic. One interpretation of this assumption is

[6] The concept of what constitutes a firm does not seat easily with our otherwise Walrasian model. Section 5 shows that our results all got through in a monopolistic competition trade model where firms are well-defined; here we stick with the HO setting to improve comparison with the four theorems.

that Foreign workers are themselves as productive or as well educated as Home workers but that Foreign technology or management practices are inferior to Home's (Bloom and Van Reenen 2007).

To be concrete about the exogenous changes that allow trade-in-tasks, we introduce "coordination costs" i.e. the cost of exchanging information necessary to coordinate various tasks into a single production process. We introduce two types of coordination costs, within- and between-firm costs:

Assumption 4 (within- and between-firm coordination costs). It costs $\chi_{it} \geq 0$ to offshore task-*t* in sector-*i* to Foreign when other tasks are undertaken within the firm; it costs an additional $\zeta_{it} \geq 0$ when the task is done by a separate firm.

We think of these as the cost of moving ideas internationally and informally associate lower χ and ζ with advances in information and communication technology. Following standard offshoring theory, χ_{it} varies across tasks. Routine tasks, which are easily codified, are cheaper to offshore than complex tasks that require frequent face-to-face interactions. To integrate trade-in-tasks results with trade-in-goods theory (where the standard thought experiment is autarky-to-free-trade), we focus on extreme changes in χ_{it}. For the routine tasks, which we call type-1 tasks, the switch is from prohibitive to zero. For complex tasks, type-2 tasks, the coordination costs remain prohibitive. Without further loss of generality, we set $N_i = 2$ for all *i*. Task $t = 1$ is the set of all tasks that can be offshored at zero coordination cost; task $t = 2$ is the set of tasks that are prohibitively expensive to offshore.

In many offshoring models (e.g. Grossman and Rossi-Hansberg 2008), the offshored tasks are provided only within the firm; no sales to local unrelated firms are allowed. As this within-firm-only assumption affects the general equilibrium in an important way, and it is not the only reasonable assumption, we consider variation in $\zeta_{it} \geq 0$ that helps or hinders between-firm sales. Depending upon the nature of the task, it may be possible to coordinate production even when some tasks are performed by other firms – especially when the task does not involve firm-specific services or components. In keeping with trade theory traditions, we consider two polar cases. The first takes the ζ's as sufficiently high to make inter-firm trade-in-tasks uneconomical, i.e. $\zeta_{i1}, \zeta_{i2} \to \infty$. The second takes $\zeta_{i1} = 0$ so the output of offshored tasks production can be bought by both Home and Foreign firms. We refer to the first case as the "no local sales" case, and the second as the "local sales" case. We study the no-local-sales case in the remainder of this section; Section 4 analyses the local-sales case.

3.1. Free trade in tasks: No-local-sales of offshored tasks

To explore the impact of trade-in-tasks, we start from the trade-in-goods equilibrium and – in the spirit of trade theory – consider the impact of an exogenous drop in χ_{it}. Specifically, the coordination costs for offshore production of type-1 tasks (routine) switch from prohibitive to zero, while the coordination costs for type-2 tasks (complex) remain prohibitive. By the usual cost-savings logic, all Home production of type-1 tasks is offshored to Foreign (assuming standard regularity conditions that ensure diversified production in both economies).[7] Formally:

Proposition 1 (trade-in-tasks occurs). Under regularity conditions that assure diversified production, all type-1 tasks are offshored from Home to Foreign in the trade-in-tasks equilibrium.

Proof. Suppose that trade in type-1 tasks was possible but none occurred in equilibrium. As this prospective equilibrium is identical to the trade-in-goods equilibrium, **w** would equal γ**w***, so by Assumption 3 an atomistic firm deviating from the prospective equilibrium would reduce costs by offshoring its type-1 tasks. The resulting pure profit contradicts the definition of a competitive equilibrium, so some trade-in-tasks occurs. To show that all Home firms offshore all type-1 tasks, note that any firm that did not fully exploit the cost-saving opportunity would earn negative profits when competing with firms that did – provided only that **w** ≥ **w***. This factor price inequality is assured by diversified production as it is not possible for Foreign firms using the inferior technology to be competitive with Home firms unless **w** ≥ **w*** by the pricing expressions in (1) (with **p*** = **p**). *QED*.

[7] The appendix of our working paper (http://www.dagliano.unimi.it/media/wp2008_250.pdf) provides exact necessary and sufficient conditions for diversification in the 2x2x2 version of the model.

Given Proposition 1, Home's pricing and employment equations reflect Foreign-factor usage (for type-1 tasks), while Foreign's pricing condition is unaffected (Foreign firms continue to use Foreign technology and pay Foreign wages). Foreign's employment condition, however, reflects offshoring employment. In the no-local-sales case, all offshore task production is re-imported to Home, so Foreign employment in the offshore sector is proportional to Home's production vector. Formally, using the subscript 'O' (for 'offshoring') to indicate trade-in-task equilibrium variables:

$$\begin{aligned} \mathbf{p_O} &= (\mathbf{A_O} - \mathbf{A_1})\mathbf{w_O} + \mathbf{A_1^*}\mathbf{w_O^*}, \qquad & \mathbf{p_O} &= \gamma \mathbf{A_O^*}\mathbf{w_O^*} \\ \mathbf{V} &= (\mathbf{A_O^T} - \mathbf{A_1^T})\mathbf{X_O}\,, \qquad & \mathbf{V}^* &= \gamma \mathbf{A_O^{*T}}\mathbf{X_O^*} + \mathbf{A_1^{*T}}\mathbf{X_O} \end{aligned} \tag{4}$$

where $\mathbf{A_O} \equiv \mathbf{A}(\mathbf{w_O})$, $\mathbf{A_1} \equiv \{a_{fi1}(\mathbf{w_O})\}$, $\mathbf{A_1^*} \equiv \{a_{fi1}(\mathbf{w_O^*})\}$, and $\mathbf{A_O^*} \equiv \mathbf{A}(\mathbf{w_O^*})$. From (4), we see the first main difference between trade-in-goods and trade-in-tasks:

Proposition 2 (effective factor price divergence). Unless there exists a real number ϕ in the unit interval such that $\mathbf{A_1} = \phi\mathbf{A}$, trade-in-tasks forces a divergence of (effective) factor prices. ($\mathbf{A_1} = \phi\mathbf{A}$ is the knife-edge case where the sets of type-1 and type-2 tasks have identical factor intensity.)

Proof. The law of one price holds, so $(\mathbf{A_O} - \mathbf{A_1})\mathbf{w_O} + \mathbf{A_1^*}\mathbf{w_O^*} = \gamma\mathbf{A_O^*}\mathbf{w_O^*}$ given (4). If Proposition 1 were false and effective FPE held, then $\mathbf{w_O} = \breve{\gamma}\mathbf{w_O^*}$ for some $\breve{\gamma} > 1$ and by Assumption 1, we would have $\mathbf{A_O^*} = \mathbf{A_O}$ and $\mathbf{A}_1^* = \mathbf{A}_1$, implying $(\mathbf{A_O} - \mathbf{A_1})\mathbf{w_O} = \breve{\gamma}^{-1}(\gamma\mathbf{A_O} - \mathbf{A_1})\mathbf{w_O}$. This expression can be true only if: (i) all factor prices are zero, which violates the zero profit condition; (ii) $\mathbf{A_1} = \mathbf{0}$, i.e. no offshoring occurs, which violates Proposition 1; or (iii) the factor intensity of type-1 tasks are exactly proportional to aggregate factor intensity in each industries, i.e. $\mathbf{A_1} = \phi\mathbf{A}$ for some $\phi \in [0,1)$. Thus the supposition that effective FPE occurs under trade in task must be false unless (iii) is true. *QED.*

Intuition for this result is simple. As authors from Jones and Kierzkowski (1990) to Grossman and Rossi-Hansberg (2008) have argued, offshoring/fragmentation/trade-in-tasks is akin to technological progress for the offshoring nation. As the new trade involves a subset of tasks and offshoring is unidirectional, the technological change is non-homothetic and this destroys effective FPE. Intuition is further served by deviating from the long-standing tradition in the fragmentation/offshoring literature by considering the case where all tasks are offshorable. In this extreme case, no goods are produced using Foreign technology as such goods would be uncompetitive with goods produced using Home technology. In short, Home technology supplants Foreign technology globally, resulting in perfect factor price equalisation.

Perhaps the most robust theoretical finding in trade theory is the HOV theorem. Does this hold when trade-in-tasks as well as trade-in-goods occurs? Given homothetic preferences, Home's consumption vector is proportional to world output, i.e. $\mathbf{C_O} = s\mathbf{X_O^w}$, however solving for $\mathbf{X_O}$ and $\mathbf{X_O^*}$ from (4):

$$\begin{aligned}\mathbf{M_O} &= s\mathbf{X_O^W} - \mathbf{X_O} \\ &= s\left\{\left[\mathbf{I} - (\gamma\mathbf{A_O^{*T}})^{-1}\mathbf{A_1^{*T}}\right](\mathbf{A_O^T} - \mathbf{A_1^T})^{-1}\mathbf{V} + (\gamma\mathbf{A_O^{*T}})^{-1}\mathbf{V}^*\right\} \quad - \quad (\mathbf{A_O^T} - \mathbf{A_1^T})^{-1}\mathbf{V}\end{aligned} \tag{5}$$

The only circumstance in which this reduces to the standard HO expression in (2) is when the offshoring matrices $\mathbf{A_1}$ and $\mathbf{A_1^*}$ are both zero – i.e. when no offshoring occurs. In short, given Proposition 1, we can say that the HO theorem breaks down with trade-in-tasks.

The GFT theorem also breaks down – a result established by application of the Dixit (1985) technique for comparing restricted trading equilibriums.[8] Under our Walrasian assumptions, the cost of combining the output of type-1 and type-2 sets of tasks into a consumable good is zero, so we can readily apply Dixit's result. We think of there being 2*I* goods (the two sets of tasks for each of the *I* goods) whose 'shadow prices' are the actual marginal production costs (i.e. including offshoring in the trade-in-tasks equilibrium). The relevant GFT condition is therefore $\bar{\mathbf{p}}_\mathbf{O}(\bar{\mathbf{C}}_\mathbf{O} - \bar{\mathbf{C}}) \geq 0$ where bars indicate the artificially extended vectors, and the price vector consists of the shadow prices (marginal costs). As before, this implies $(\bar{\mathbf{p}} - \bar{\mathbf{p}}_\mathbf{O})\bar{\mathbf{M}} + \bar{\mathbf{p}}_\mathbf{O}(\bar{\mathbf{X}}_\mathbf{O} - \bar{\mathbf{X}}) \geq 0$ due the definition of imports and the fact that trade balance implies $\bar{\mathbf{p}}\bar{\mathbf{M}} = \bar{\mathbf{p}}_\mathbf{O}\bar{\mathbf{M}}_\mathbf{O} = 0$. Profit maximisation assures that $\bar{\mathbf{p}}_\mathbf{O}(\bar{\mathbf{X}}_\mathbf{O} - \bar{\mathbf{X}})$ is positive, but the term $(\bar{\mathbf{p}} - \bar{\mathbf{p}}_\mathbf{O})\bar{\mathbf{M}}$ can be positive or negative; indeed, this is the Laspeyres index of Home's terms-of-

[8] In independent work, Markusen (2010) derives a result; assuming all goods are traded domestically and some also internationally, he shows that allowing more to be traded internationally yields ambiguous GFT with a terms of trade improvement being a sufficient condition for a gain.

trade loss when trade-in-tasks is allowed. Offshoring could, for example, boost global production of Home exports more than Home's imports, engendering a terms-of-trade loss. Relative output, however, could fall in the opposite direction, so the terms-of-trade impact is ambiguous. Isomorphic reasoning implies Foreign GFT are also not assured, but the zero-sum nature of terms-of-trade effects alerts us to the fact that at least one nation must gain from offshoring. If goods prices are unaffected by trade-in-tasks, Home gains and Foreign is unaffected (Foreign is also strictly better off in the model of Section 4). Formally (proof in the text), we write:

Proposition 3: (ambiguous GFT from trade-in-tasks). Trade-in-tasks is Pareto improving if terms-of-trade are unaffected and global welfare rises in all cases as terms-of-trade effects disappear at the global level. If Home or Foreign loses from trade-in-tasks, then the other nation must gain. A necessary condition for a nation to lose is that it experiences a terms-of-trade loss.

3.2. The integrating framework: The shadow migration approach

Proposition 2 and expressions (4) and (5) reveal that trade-in-tasks ruins much of the HO model's elegance, and this for three reasons. First, by Proposition 1, Home and Foreign choose different positions on their isoquants so the **A** matrices are not proportional. Second, even if techniques were invariant to factor prices (Leontief), (4) shows that Home and Foreign goods are produced with different technologies where the differences are non-homothetic except in the knife edge case of $\mathbf{A}_1 = \phi\mathbf{A}_\mathbf{O}$. Third, some Foreign factors use Foreign technology while others use Home technology. Each problem disrupts the elegant flow of HO logic.

A key contribution of our paper is to suggest a transformation of the model that restores much of the HO elegance and does so in a way that enables us to integrate trade-in-tasks theory into the received body of trade-in-goods theory. It also allows us to integrate the wide range of special cases considered in the offshoring literature. The transformation turns on the insight that offshoring is like "shadow migration". That is, Home firms employ Foreign factors to produce tasks using Home technology, so offshoring affects the equilibrium in a way akin to migration of Foreign factors to Home assuming the migrated factors were paid foreign wages rather than Home wages.

The shadow-migration transformation has two manifestations – one for quantities and one for prices – with each involving the introduction of a new vector. The shadow migration vector, denoted as $\Delta\mathbf{V}$, equals the vector of Foreign factors employed in performing the offshored tasks, i.e. $\mathbf{A}_1^{*\mathbf{T}}\mathbf{X_O}$. The offshoring cost-saving vector, denoted as $\mathbf{S}$, equals the difference between the cost of performing the offshored tasks in Home and Foreign, i.e. $\mathbf{A_1 w_O} - \mathbf{A}_1^*\mathbf{w}_\mathbf{O}^*$. Both are potentially observable given modern datasets as they require only information on the offshored production (in addition to the usual information of **w**'s, **X**'s and **A**'s).

Approximating around the trade-in-goods **A(w)**, the trade-in-tasks employment conditions in terms of shadow-migration-adjusted endowments (denoted $\mathbf{V_O}$ and $\mathbf{V}_\mathbf{O}^*$) are:

$$\mathbf{V_O} = \mathbf{A^T X_O} + \mathbf{R}_1, \quad \mathbf{V}_\mathbf{O}^* = \gamma\mathbf{A^{*T}}\,\mathbf{X}_\mathbf{O}^* + \mathbf{R}_2 \tag{6}$$

where the Foreign shadow-migration-adjusted endowment is $\mathbf{V}_\mathbf{O}^* \equiv \mathbf{V}^* - \Delta\mathbf{V}$ with $\Delta\mathbf{V} \equiv \mathbf{A}_1^{*\mathbf{T}}\mathbf{X_O} > 0$, and $\mathbf{R_2}$ is the remainder from a Taylor expansion of **A** around **w** weighted by $\mathbf{X}_\mathbf{O}^*$.[9] Also, $\mathbf{V_O}$ and $\mathbf{R_1}$ are the Home versions of $\mathbf{V}_\mathbf{O}^*$ and $\mathbf{R_2}$ with an additional approximation that comes from the fact that (due to effective factor price divergence) $\Delta\mathbf{V}$ may not exactly equal the vector of Home factors that would be necessary to produce the offshored tasks, i.e. $\mathbf{V_O} \equiv \mathbf{V} + \Delta\mathbf{V} + \mathbf{R}_3$ where

$\mathbf{R_3}$ equals $\left(\mathbf{A}_1^\mathbf{T} - \mathbf{A}_1^{*\mathbf{T}}\right)\mathbf{X_O}$. Similarly, the transformed pricing equations are:

$$\mathbf{p_O} + \mathbf{S} = \mathbf{A w_O} + \mathbf{R}_5, \qquad \mathbf{p_O} = \gamma\mathbf{A}^*\mathbf{w}_\mathbf{O}^* + \mathbf{R}_6 \tag{7}$$

where $\mathbf{S} \equiv \mathbf{A_1 w_O} - \mathbf{A}_1^*\mathbf{w}_\mathbf{O}^*$ is the vector of cost-savings, and the **R**'s are Taylor expansions arising from the approximation around **A(w)** as before.

---

[9] More precisely, the infinite order Taylor expansion approximation is $\mathbf{A^T}(\mathbf{w}_\mathbf{O}^*) = \mathbf{A^T}(\mathbf{w}^*) + \frac{\nabla\mathbf{A^T}(\mathbf{w}^*)}{\nabla\mathbf{w}}(\mathbf{w}_\mathbf{O}^* - \mathbf{w}^*) + \mathbf{H}$ where H includes the higher order terms. Thus $\mathbf{R}_2 \equiv \gamma\left(\frac{\nabla\mathbf{A^T}(\mathbf{w}^*)}{\nabla\mathbf{w}}(\mathbf{w}_\mathbf{O}^* - \mathbf{w}^*) + \mathbf{H}\right)\mathbf{X}_\mathbf{O}^*$.

The **R**'s are negligible – and the trade-in-task employment and pricing conditions, (6) and (7), are isomorphic to those of the HO model, (1) – in two cases: (i) when the changes in the χ's are such that the scale of offshoring is modest, so factor-prices changes are modest and **A** changes are second-order-small by the envelope theorem; and (ii) when the technology is such that the a_{fi}'s are not very sensitive to factor prices so **A** changes are modest even for large factor-price changes; Leontief technology is the extreme of fully insensitive technique choices implying all **R**'s are identically zero.

Using the shadow-migration transformed employment conditions, (6), and approximating the Taylor expansion remainders as zero, Home's import under trade-in-tasks, $\mathbf{M_O}$, is related to endowments by:

$$\begin{aligned}\mathbf{M_O} &= s\mathbf{X_O^W} - \mathbf{X_O} \\ &= (\mathbf{A^T})^{-1}\left(s\tilde{\mathbf{V}}_\mathbf{O}^w - \mathbf{V_O}\right)\end{aligned} \tag{8}$$

where $\tilde{\mathbf{V}}_\mathbf{O}^w \equiv \tilde{\mathbf{V}}^w + (1-\gamma^{-1})\Delta\mathbf{V}$. Inspection of this yields (proof in the text):

Proposition 4 (trade-in-tasks analogue to HO and HOV theorems). The pattern of goods-trade in the trade-in-tasks equilibrium is explained by the HO theorem where actual endowments are replaced by shadow-migration-adjusted endowments.

This is subject to the usual provisos that apply to higher-dimension versions of the HO and HOV theorems (see Ethier (1974, 1984), or Dixit and Norman (1980)) as well as the well-known provisos that come with Taylor-expansion approximations.

A number of implications of this proposition are noteworthy and potentially testable. Switching to the HOV approach and using the definition of $\tilde{\mathbf{V}}_\mathbf{O}^w$:

$$\left(s\tilde{\mathbf{V}}^w - \mathbf{V}\right) - \mathbf{A^T M_O} = \left[1 - s(1-\gamma^{-1})\right]\Delta\mathbf{V} \tag{9}$$

The HOV theorem asserts that the left-side should be zero (see (2)), but with trade-in-tasks:

Corollary 4.1: The difference between the factor-content predicted by the HOV theorem and the measured factor-content of Home's import vector, $\mathbf{A^T M_O}$, is proportional to but smaller than the shadow migration vector $\Delta\mathbf{V}$.

For example, in the 2x2x2 case where Home is skill-abundant but coordination costs are such that the offshored tasks are particularly unskilled intensive, Home's shadow-migration-adjusted endowment is skewed towards unskilled labour, so, as per Proposition 4, it may import the skill-intensive good for reasons that are conceptually different from the exogenous Ricardian differences suggested by Leontief (1953) and confirmed by Trefler (1993).

If the offshored tasks are intangible – e.g. accounting services – Home will be importing 'invisible' tasks from Foreign. As the factor content of this could be measured with data on offshore production, predictions for the total factor content of 'visible' and 'invisible' trade may be testable. From (9), $\left(s\tilde{\mathbf{V}}^{w}-\mathbf{V}\right)-(\mathbf{A}^{T}\mathbf{M}_{O}+\Delta\mathbf{V})=-s(1-\gamma^{-1})\Delta\mathbf{V}$ and combining this with Corollary 4.1 we have:

Corollary 4.2 (bounded HOV errors): In the presence of trade-in-tasks, the standard HOV factor-content prediction, $s\tilde{\mathbf{V}}^{w}-\mathbf{V}$, should overstate the factor-content of final-goods trade but understate the factor-content of final-goods trade plus that of trade-in-tasks. More precisely, the factor-content of final-goods and traded tasks are $\mathbf{A}^{T}\mathbf{M}_{O}$ and $\Delta\mathbf{V}$ respectively, so the following bounds should hold: $\mathbf{A}^{T}\mathbf{M}_{O}<s\tilde{\mathbf{V}}^{w}-\mathbf{V}<\mathbf{A}^{T}\mathbf{M}_{O}+\Delta\mathbf{V}$.

The proof is by inspection of (9) noting that every element of $\Delta\mathbf{V}$ is non-negative.

If the offshored tasks yield firm-specific intermediate goods, we have:

Corollary 4.3 (intraindustry trade): If the offshored tasks produce intermediate goods then intraindustry trade must arise.

Proof. Every sector offshores some task (Proposition 1) so Home's vector of imported intermediates is strictly positive. From Proposition 4, Home exports some final goods, so Home engages in intraindustry trade in each of its export sectors (assuming the intermediate goods are classified in the same industry as their corresponding final good). *QED*.

Corollary 4.4 (source of comparative advantage): Offshoring is a source of comparative advantage in the sense that trade-in-tasks creates trade-in-goods that would not occur otherwise.

The general proof is simply a restatement of the fact that offshoring alters the pattern of trade, as per Proposition 4 or inspection of (8). Intuition, however, is served by illustrating Corollary 4.4 with an example. Consider the special case where Home and Foreign have proportional factor endowments (i.e. $\mathbf{V} = b\mathbf{V}^*$, $b > 0$), so no trade occurs in the trade-in-goods equilibrium. Allowing trade-in-tasks creates trade in final goods (except in the usual knife-edge case $\mathbf{A_1} = \phi\mathbf{A}$) as Foreign will export the output of type-1 tasks (Proposition 1) and Home must export final goods to balance trade.

Proposition 5 (trade-in-tasks analogue to FPE theorem). Starting from the trade-in-goods equilibrium, allowing trade-in-tasks produces a divergence in effective factor prices that is proportional to the value of the cost-saving stemming from trade-in-tasks.

The proof is by inspection of (7). Under the trade-in-goods equilibrium, effective factor price equalisation, $\mathbf{w} = \gamma\mathbf{w}^*$, holds. Trade in tasks changes all goods and factor prices, in general, but the effective factor price gap – ignoring Taylor expansion remainders – is:

$$\mathbf{w_O} - \gamma\mathbf{w_O^*} = \mathbf{A}^{-1}\mathbf{S} \tag{10}$$

QED.

An implication, whose proof is by inspection of (10), is:

Corollary 5.1 (shadow migration not necessarily a substitute for real migration). From Proposition 5, shadow migration can widen or narrow the international wage gap for each type of labour, so offshoring may increase or decrease the pressure for real migration.

Given (6) and (7), and assuming the Taylor expansion remainders are negligible, analogues for the Rybczynski and Stolper-Samuelson theorems are straightforward. From (6), approximating the remainders as zero, $\mathbf{V_O} = \mathbf{A^T X_O}$, so $\mathbf{X_O} = (\mathbf{A^T})^{-1}(\mathbf{V} + \Delta\mathbf{V})$ while before trade-in-tasks $\mathbf{X} = (\mathbf{A^T})^{-1}\mathbf{V}$; analogous expressions hold for $\mathbf{X_O^*}$ and $\mathbf{X}^*$. Inverting the Home pricing equation in (7), $\mathbf{w_O} = \mathbf{A}^{-1}(\mathbf{p_O} + \mathbf{S})$ while under the trade-in-goods equilibrium, $\mathbf{w} = \mathbf{A}^{-1}\mathbf{p}$; Foreign wages are only affected by price changes. With $\Delta\mathbf{p} \equiv \mathbf{p_O} - \mathbf{p}$, the equations of change are:

$$\begin{aligned} &\mathbf{X_O} - \mathbf{X} = (\mathbf{A^T})^{-1}\Delta\mathbf{V}\,, \qquad \mathbf{X_O^*} - \mathbf{X}^* = -(\gamma\mathbf{A^T})^{-1}\Delta\mathbf{V} \\ &\mathbf{w_O} - \mathbf{w} = \mathbf{A}^{-1}(\Delta\mathbf{p} + \mathbf{S})\,, \qquad \mathbf{w_O^*} - \mathbf{w}^* = \left(\gamma\mathbf{A}\right)^{-1}\Delta\mathbf{p} \end{aligned} \tag{11}$$

Proposition 6 (trade-in-tasks analogue to Rybczynski theorem). Starting from free trade-in-goods, allowing trade-in-tasks affects production in exactly the way predicted by the standard Rybczynski theorem with the implied 'shadow migration' replacing the usual exogenous variation of factor endowments. Standard Jonesian magnification effects occur.

This is subject to the usual provisos that apply to higher dimensional versions of the original Rybczynski theorem. Also:

Proposition 7 (Trade-in-tasks analogue to Stolper-Samuelson theorem). Starting from free trade in goods, allowing trade-in-tasks affects Home factor prices in exactly the way predicted by the standard Stolper-Samuelson theorem with the vector of cost-savings from offshoring **S** coming in addition to the usual exogenous variation in prices.

This is subject to the usual provisos that apply to higher dimensional versions of the original Stoler-Samuelson theorem.

The proofs are by inspection of (11), noting that the production-change and the wage change problems have been reduced to the standard Rybczynski and Stolper-Samuelson theorem thought-experiments (respectively), so the impact on production is as predicted by the Rybczynski and Stolper-Samuelson theorems.

Standard trade theory rarely addresses the impact of free trade on global output. With trade-in-tasks, however, there are important and systematic global changes in output since shadow migration expands the effective world endowments, i.e. $\tilde{\mathbf{V}}_{\mathbf{O}}^{w} > \tilde{\mathbf{V}}^{w}$. From (11) and the definition of $\mathbf{X^W}$ we get:

$$\mathbf{X_O^W} - \mathbf{X^W} = (1-\gamma^{-1})(\mathbf{A^T})^{-1}\Delta\mathbf{V} \tag{12}$$

Proposition 8 (global production effects). If trade-in-tasks produces shadow migration in only one factor, then global production of at least one good must rise and that of at least one other good must fall.

Proof is by the usual Ethier (1984) approach to the *I* x *F* version of the Rybczynski theorem.[10]

As a minor corollary, we note the expansion of the shadow-migration-adjusted world endowment vector is proportional to the augmentation of Home's shadow-migration-adjusted endowment, thus the global production effects tend to be proportional to Home's production effects as shown by comparison of (11) and (12).

3.3. The 2x2x2 example

The 2x2x2 version of the HO model is a key source of theoretical insights for trade-in-goods and a workhorse of the offshoring/trade-in-tasks literature. Here we present the analytic solutions for the trade-in-tasks and trade-in-goods equilibrium in a 2x2x2 example.

The two factors (skilled labour *K* and unskilled labour *L*) are paid *r* and *w*, respectively and work in the *X* and *Y* sectors. *X* is numeraire and *L*-intensive (i.e. $\kappa_Y > \kappa_X$ where $\kappa_i \equiv a_{Ki} / a_{Li}$ for $i = X$, Y). Foreign is abundantly endowed with unskilled labour (i.e. $k^* < k$ where $k \equiv K / L$ and $k^* \equiv K^* / L^*$). To ensure diversified production with free trade in goods, we assume $\kappa_Y > k > k^* > \kappa_X$ when the κ's are evaluated at the equilibrium factor prices.

Inverting expressions in (1) yields solutions for **w**'s and **X**'s in the trade-in-goods equilibrium:

$$\mathbf{w} = \mathbf{A}^{-1}\mathbf{p}, \quad \mathbf{X} = (\mathbf{A}^{\mathrm{T}})^{-1}\mathbf{V}, \quad \mathbf{w}^* = \gamma^{-1}\mathbf{A}^{-1}\mathbf{p}, \quad \mathbf{X}^* = \gamma^{-1}(\mathbf{A}^{\mathrm{T}})^{-1}\mathbf{V}^*, \tag{13}$$

where

$$\mathbf{w} \equiv \begin{bmatrix} w \\ r \end{bmatrix}, \quad \mathbf{p} \equiv \begin{bmatrix} 1 \\ p \end{bmatrix}, \quad \mathbf{V} \equiv \begin{bmatrix} L \\ K \end{bmatrix}, \quad X \equiv \begin{bmatrix} X \\ Y \end{bmatrix}, \quad X \equiv \begin{bmatrix} X \\ Y \end{bmatrix}, \quad \mathbf{A} \equiv \begin{bmatrix} a_{LX} & a_{KX} \\ a_{LY} & a_{KY} \end{bmatrix}, \quad \mathbf{A_1} \equiv \begin{bmatrix} a_{LX1} & a_{KX1} \\ a_{LY1} & a_{KY1} \end{bmatrix}$$

and from global market-clearing:

[10] From the employment condition of the expanding factor, we know that the proportional expansion in the factor equals the average of the proportional changes in outputs weighted by employment-shares (Jones algebra). From the employment condition for some non-expanding factor, we know that the employment-share-weighted average proportional changes in output must be zero. The only way both can be true is if at least one output expands and one contracts.

$$p = \frac{\alpha/(1-\alpha)}{a_{LX}\ /\ a_{LY}} \ \frac{\kappa_Y - k^w}{\tilde{k}^w - \kappa_X}; \qquad \tilde{k}^w \equiv \frac{K + K^*/\gamma}{L + L^*/\gamma}$$

Here $\alpha(\cdot) \in (0,1)$ denotes the equilibrium expenditure share on *Y*.

Next consider the trade-in-tasks equilibrium. Solving (6) and (7) for $\mathbf{X_O}$ and $\mathbf{w_O}$ (ignoring the remainders) and using (13) yields:

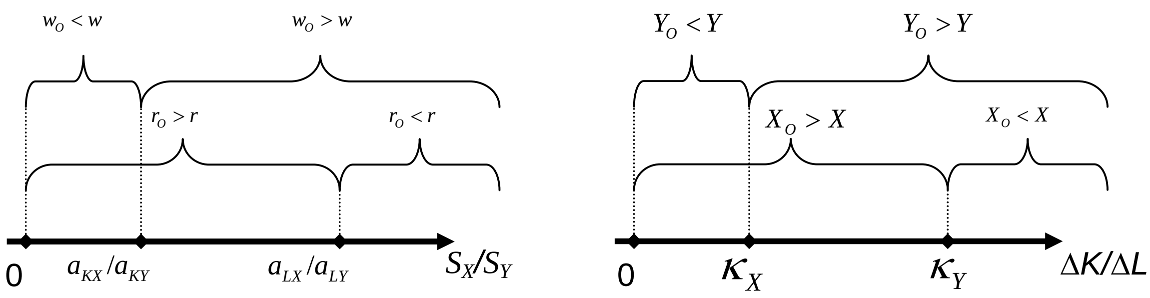
$$\begin{aligned} X_O - X &= (\frac{1}{a_{LY}})\frac{\kappa_Y \Delta L - \Delta K}{\kappa_Y - \kappa_X}, & Y_O - Y &= (\frac{1}{a_{LY}})\frac{\Delta K - \kappa_X \Delta L}{\kappa_Y - \kappa_X} \\ w_O - w &= \frac{a_{KY} S_X - a_{KX} S_Y}{a_{LX} a_{LY}(\kappa_Y - \kappa_X)} + A^{-1}\begin{bmatrix} 0 \\ \Delta p \end{bmatrix}, & r_O - r &= \frac{a_{LX} S_Y - a_{LY} S_X}{a_{LX} a_{LY}(\kappa_Y - \kappa_X)} + A^{-1}\begin{bmatrix} 0 \\ \Delta p \end{bmatrix} \end{aligned} \tag{14}$$

where Δp equals $p_O - p$, $S_X = a_{LX1}(w_O - w_O^*) + a_{KX1}(r_O - r_O^*)$ and $S_Y = a_{LY1}(w_O - w_O^*) + a_{KY1}(r_O - r_O^*)$. These are examples of Proposition 6 and 7, and we note that Jonesian magnification effects are in operation.[11]

Expression (14) shows the necessary and sufficient conditions for signing production and wage effects of trade-in-tasks. Rather than write out the results in the form of propositions, we depicted the full range of outcomes in Figure 1. For example, if shadow migration is heavily skewed towards *L* (specifically, $\Delta K/\Delta L$ is less than the capital intensive of *X*, κ_X) then *X* rises and *Y* falls. If shadow migration has an intermediate factor ratio, namely $\kappa_X < \Delta K/\Delta L < \kappa_Y$, then both *X* and *Y* rise. Finally, if it is heavily skewed towards *K* ($\Delta K/\Delta L > \kappa_Y$) then *X* falls and *Y* rises. Foreign production effects are characterised in an isomorphic manner.

Figure 1: Necessary and sufficient conditions for wage and production effects due to trade in tasks.

[11] For example, $\Delta X/X = \{(\Delta L/L)\ /(1- k/\kappa_Y) - (\Delta K/K)/(\kappa_Y/k-1)\}$ and $k/\kappa_Y < 1$ since both economies' product is diversified.



Turning to the wage effects, we see from (14) that the wage of Home *L*-workers rises (controlling for terms-of-trade effects) if and only if the cost-saving is sufficiently greater in the *L*-intensive sector than in the *K*-intensive sector, namely $S_X / S_Y > a_{KX} / a_{KY}$; in this case *r* rises less or actually falls. The necessary and sufficient condition for *r* to fall (controlling for relative prices), is that the ratio of cost-savings exceeds the ratio of *L*-input coefficients, $S_X / S_Y > a_{LX} / a_{LY}$. If the cost-savings ratio lies between the skilled-unskilled endowment ratios then both *w* and *r* rise by the direct effect. Apart from terms-of-trade effects, i.e. Δp, trade-in-tasks has no effect on foreign wages in the no-local-sales case we are considering (this changes in the local-sales case considered below).

3.4. Integrating special cases in the literature

The theoretical trade-in-tasks literature has focused on special cases. Here we illustrate how the various cases fit together. As most the literature works with what are effectively 2x2x2 models and ignore terms-of-trade effects (i.e. small country assumption), we follow suit. In this case, the impact of offshoring on *w* and *r* are given by the bottom row of (14) taking $\Delta p = 0$.

Many papers assume that offshoring occurs in only a single sector. This includes Jones and Kierzkowski (1990) and follow-on papers,[12] Deardorff (1998a), Venables (1999), Kohler (2004a, b), and Markusen (2006). In such papers, either $S_X = 0$ or $S_Y = 0$, so offshoring acts like sector-specific technical progress. The wage effects thus depend on the factor intensity of the

[12] For example, Jones and Marjit (1992), Arndt (1997, 1999), Jones and Kierzkowski (1998, 2000), and Jones, Kierzkowski and Leonard (2002). Francois (1990a, b, c) explicitly considers the impact of offshoring on the factor price equalization set.

progressing sector; offshoring only in the *L*-intensive *X* sector raises *w* and lowers *r*; while offshoring only in *Y* does the opposite, as (14) shows.

Other papers consider offshoring involving only one factor but in both sectors, so offshoring is like factor-specific technical progress, specifically $S_X = a_{LX1}(w_O - w_O^*)$ and $S_Y = a_{LY1}(w_O - w_O^*)$. As is well known, factor-specific technical progress has ambiguous effects on *w* and *r* (Jones 1965); what matters is the relative size of the cost savings by sector – the necessary and sufficient conditions are summarised by the left-panel in Figure 1.

Perhaps the most famous special case in the literature is the Grossman and Rossi-Hansberg (2006) result (repeated in the main body of analysis of their 2008 paper) that unskilled labour unambiguously gains from the offshoring of unskilled-intensive tasks while the other factor's wage effect is exactly zero. How does this fit in with the ambiguity apparent in (14)? As it turns out, the result is driven by the concatenation of three normalisations. Working in what could be boiled down to a 2x2x2 model, they describe each sector's production process as involving two continuums of tasks – one that uses only *L*, the other only *K*. The four continuums are normalised to the unit interval, and within each continuum, tasks are normalised to use the same amount of the relevant factor. After ordering the tasks by increasing offshoring costs, they normalise the offshoring costs across sectors. In the famous special case, only *L*-tasks are offshoreable, but the three normalisations imply that exactly the same fraction of *L* is offshored in *X* and *Y*. In our notations $S_X = \lambda a_{LX}(w_O - w_O^*)$ and $S_Y = \lambda a_{LY}(w_O - w_O^*)$, where λ is the endogenous fraction. As (14) shows, proportional offshoring of a single factor produces the famous special case. Specifically, all the cost-saving goes to *L*, i.e. $r_O - r = 0$ and $w_O - w = \lambda a_{LX}(w_O - w_O^*)$. Ambiguity of the wage effects is restored in subsequent analysis in Grossman and Rossi-Hansberg (2008) when the cross-sector normalisation is dropped, or offshoring of *H*-tasks is allowed.

4. Offshoring with local sales

In the previous section, all output of the offshored sector was 'sold' to Home. Here we allow local sales of offshored tasks by assuming the inter-firm coordination costs, the ζ's, are zero.[13]

With zero inter-firm coordination costs, Home firms have an incentive to sell type-1 tasks to Foreign producers as their superior technology gives them an edge over local producers. Taking all remainders as zero in this sector to reduce clutter, the pricing and employment equations with local sales of offshored tasks are:

$$\mathbf{p}+\mathbf{S}=\mathbf{A}\mathbf{w}_{\mathbf{O}}, \qquad \mathbf{p}+\mathbf{S}^*=\gamma\mathbf{A}\mathbf{w}^*_{\mathbf{O}}; \qquad \mathbf{V}+\Delta\mathbf{V}=\mathbf{A}^{\mathbf{T}}\mathbf{X}_{\mathbf{O}}, \qquad \mathbf{V}^*+\Delta\mathbf{V}^*=\gamma\mathbf{A}^{\mathbf{T}}\mathbf{X}^*_{\mathbf{O}} \tag{15}$$

where **S** and Δ**V** are defined as in Section 3, but now Foreigners benefit directly from offshoring's cost saving, so $\mathbf{S}^*=(\gamma-1)\mathbf{A}_1(\mathbf{w}_{\mathbf{O}}-\mathbf{w}^*_{\mathbf{O}})>0$ and $\Delta\mathbf{V}^*=\mathbf{A}^{\mathbf{T}}\mathbf{X}^*_{\mathbf{O}}$. Importantly, **S*** > 0 means Foreign wages are directly affected by trade-in-tasks whereas they were only indirect effected via terms-of-trade effects in the no-local-sales case. Solving (15) and (1) for wages:

$$\mathbf{w}_{\mathbf{O}}-\mathbf{w}=\mathbf{A}^{-1}(\mathbf{S}+\Delta\mathbf{p}), \qquad \mathbf{w}^*_{\mathbf{O}}-\mathbf{w}^*=\mathbf{A}^{-1}(\mathbf{S}^*+\Delta\mathbf{p}) \tag{16}$$

The expression for Home factor prices is isomorphic to the no-local-sales case in the previous section (although the values of S_X and S_Y may change since the factor prices will in general be different).

There is a crucial difference, though, between the factor price effects on Home versus Foreign labour. For Home labour, it is *rents* that generate the cost-savings (i.e. the fact that Foreign workers are paid less than their average products); for Foreign labour it is *technology transfer* that generates the cost-savings. Nevertheless, the Foreign wage changes in (16) are isomorphic to those of Home. Consequently, all the detailed analysis in the previous section relating the cost-savings to the wage effects is now applicable to the impact of offshoring on Foreign wages with S^*_X and S^*_Y substituted for S_X and S_Y.

Solving (15) for production and using (13) yields:

[13] This version of the model can also be thought of as capturing long-run technology spillovers brought about by FDI. In an augmented model, local Foreign firms might close the technology gap by learning from the presence of Home offshore production.

$$\mathbf{X_O} - \mathbf{X} = (\mathbf{A^T})^{-1}\Delta\mathbf{V}, \qquad \mathbf{X_O^*} - \mathbf{X^*} = \gamma^{-1}(\mathbf{A^T})^{-1}\Delta\mathbf{V^*},$$

Qualitatively, the impact on Home production is the same as in the service-offshoring case in the previous section. The impact on Foreign production, however, is qualitatively different and the shadow migration interpretation is less clear-cut – note in particular that the signs of the elements of $\Delta\mathbf{V}$, namely ΔL^* and ΔK^*, are now ambiguous, though effective world endowments of L and K are unambiguously larger with offshoring, i.e. $\tilde{\mathbf{V}}_\mathbf{O}^w > \tilde{\mathbf{V}}^w$. In the no-local-sales case, Home offshored technology that was used only for Home production, so the Foreign labour employed in the offshoring sector was diverted from Foreign production and this meant that the Foreign production change was proportional to the Home production effect but of the opposite sign. Here the tech-transfer embodied in offshoring tends to stimulate Foreign production, so this simple proportionality breaks down. Nevertheless, the basic analysis of production effects for Foreign follows the reasoning of Proposition 4 and Figure 1 with $\Delta\mathbf{X}^*$ substituted for $\Delta\mathbf{X}$. Since the trade effects follow from the production and factor price changes, it is clear that offshoring in the local-sales case at hand will also be a source of comparative advantage and intra-industry trade.

To summarise, the main difference between the two cases is that offshoring with local-sales spreads some of the benefit of the implicit technology transfers to Foreign factors whereas in the no-local-sales case all the benefits accrued to Home factors (modulo terms of trade effects).

5. Extending the basic model

The integrating model can be easily extended to allow Ricardian differences among nations that result in two-way offshoring – a common phenomenon among OECD nations (Amiti and Wei 2005) – and to incorporate monopolistic competition a la Helpman and Krugman (1985).

5.1. Intra-industry two-way offshoring [14]

Davis (1995) shows that intraindustry trade arises in a HO-like model due to minor technological differences among nations when there are more goods than factors. As many production patterns are consistent with (1) when $I > F$, even minor technological advantages can shift global production of individual goods to a single nation. We apply this insight to generate two-way

[14] We would like to thank Toshi Okubo for providing the idea for this section.

trade-in-tasks that arises from task-level technology differences across nations (e.g. Italy may be especially excellent at making brakes for small cars, while France may be especially excellent at making air bags for small cars, even though France and Italy are roughly at parity when it comes to small car technology).

To implement this idea cleanly, we eliminate all macro differences between Home and Foreign by assuming $\gamma = 1$, and **V** = **V***. The trade-in-goods equilibrium is thus marked by absolute FPE and zero trade. There are, however, task-level technology differences in the sense that Foreign's task technology is as in (3), but Home's task technology is now:

$$a_{fi}(\mathbf{w}) \equiv \sum_{t=1}^{N_i} \varepsilon_{it} a_{fit}(\mathbf{w}) \,; \qquad \forall\ f = 1,\ldots,F;\ i = 1,\ldots,I$$

where $\varepsilon \in [1-\mu, 1+\mu]$ is a random variable that is iid across sectors and tasks, symmetrically distributed around $\mathrm{E}\{\varepsilon\} = 1$ and with $\mu > 0$.

Assuming coordination costs such that $\zeta_{it} = 0$ and $\chi_{it} = 0$ for all *i* and *t*, all tasks are potentially offshorable and firms can supply tasks to one another. We also assume that N_i is sufficiently large for all industries (or assuming a continuum of tasks) so that $a_{fi}(\cdot)$ is the same in Home and Foreign; thus, factor prices are equalised and Home is competitive in all tasks where $\varepsilon_{it} < 1$; Foreign is has the edge in all other tasks. To see this, note that the cost of producing task *t* in sector *i* at Home is $\sum_{f=1}^{F} \varepsilon_{it} a_{fit} w_{fi}$, while the cost of producing it in Foreign is isomorphic with all the ε's set to unity. Assuming the N_i's are large, the law of large numbers implies that Home has the edge in half the tasks sector-by-sector. Moreover, the tasks in which Home has the Ricardian comparative advantage will be a random sample of all tasks, so the Home employment condition will be:

$$\mathbf{V} = \frac{1}{2}\mathbf{A}^{\mathbf{T}}\mathbf{X} + \frac{1}{2}\mathbf{A}^{\mathbf{T}}\mathbf{X}^*$$

As Home and Foreign are symmetric at the macro level, it is clear that trade-in-tasks will have no impact on the **w**'s or **X**'s, but intraindustry offshoring and intraindustry trade-in-tasks will arise. There are no terms-of-trade effects, so gains from trade-in-tasks are assured. To see this, note that $\mathbf{A}_{\mathbf{O}}^{\mathbf{T}} = \frac{1}{2}\left[1 + F_{\varepsilon}(1)\right]\mathbf{A}^{\mathbf{T}} = \frac{3}{4}\mathbf{A}^{\mathbf{T}} < \mathbf{A}^{\mathbf{T}}$ holds (by the law of large numbers), where $F_{\varepsilon}(\cdot)$ is the CDF of ε. Further, all factor owners are better off if preferences are homothetic; to see this, note that $\mathbf{w_O} > \mathbf{w}$ follows by unit cost pricing ($\mathbf{w_O} = \mathbf{A_O^{-1}p_O}$ and $\mathbf{w} = \mathbf{A}^{-1}\mathbf{p}$) and homothetic preferences imply $\mathbf{p_O} = \mathbf{p}$.

5.2. Offshoring in a Helpman-Krugman trade model

A fact that has been well appreciated in trade theory since Helpman and Krugman (1985) is that the basic HOV results carry through unaltered in a Dixit-Stiglitz monopolistic competition setting provided that the increasing returns technology is homothetic, i.e. the cost function is $(mx + F)\Sigma_f a_{if} w_f$ where the summation is over all factors, m is a parameter that governs marginal cost, x is firm-level output, and F is the standard fixed cost. Here we use this insight to show that the above analysis could easily be conducted in a monopolistic competition trade model setting.

The key to the Section-3 analysis lies in the pricing and employment equations and their restatement using the shadow migration insight. As is well known, the free-entry output of a typical variety under monopolistic competition with homothetic technologies depends only on cost and taste parameters and so does not vary across the equilibriums we consider. This implies that monopolistic competition sectors display constant returns at the sector level (doubling sectoral output at equilibrium would require double the inputs), specifically, $X = n\bar{x}$ is the sector's total output where $\bar{x}$ is the invariant firm-level output. The sector's employment of factor f is thus $n\bar{x}(m + F/\bar{x})a_{if}$ where i is the Dixit-Stiglitz sector. Likewise the price of the Dixit-Stiglitz sector equals average cost, namely $(m + F/\bar{x})\sum_{f=1}^{F} a_{if} w_f$. Choosing units such that $m + F/\bar{x}$ is unity, the employment and pricing equations for this model are identical to those of the HO model of Section 3, as are the Foreign pricing and employment conditions. With this, we have reduced the problem to the one solved in Sections 3, so can conclude that the relevant Propositions also in a model that allows monopolistic competition.

6. Concluding remarks

Recent theoretical contributions have renewed interest in characterising the effects of offshoring and the result has been a wide range of cases that generate unexpected results – many which seem to contradict intuition based on standard trade theory. This paper is an attempt to integrate the theoretical trade-in-tasks literature into standard trade-in-goods theory. We present a simple modification of the HO model that allows us to consider trade-in-goods in the traditional sense (i.e., the exogenous shift from no-trade to free-trade in goods) as well as trade-in-tasks (i.e. the exogenous shift from no-trade-in-tasks to free-trade in a range of routine tasks).

The expressions for the trade and production patterns, and goods and factor prices are highly complex in the trade-in-tasks equilibrium and clearly violate the standard HO predictions. However, if one views offshoring as ‘shadow migration’, and uses shadow-migration adjusted endowments instead of actual endowments, the HO trade and production predictions work perfectly. As such, we can use the elegant HO theorems to establish necessary and sufficient conditions for the trade and production effects of offshoring. As the quantities of factors employed in offshore production is potentially observable with firm-level datasets, these trade-in-tasks analogues of the HO, HOV and Rybczynski theorems are testable in principle. We also show that offshoring creates intra-industry trade when the various tasks are considered as being in the same sector. On the price side, we show the using the vector of the cost-savings the ‘shadow migration’ produces can be used to develop trade-in-tasks analogues of the FPE and Stolper-Samuelson theorems.

Our integrating framework does not encompass the many important contributions in the offshoring literature that focus on issues of corporate governance, e.g. Grossman and Helpman (2002). These papers typically focus on the division of rents and how they depend upon the corporate structure chosen. As the division of rents will affect the division of the benefits from offshoring, we conjecture that it could have significant general equilibrium effects as well as the more direct effects on ownership. Incorporating such issues would seem to be an important topic for future theoretical research.

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